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(54) Title of the invention: Mobile-Object Communication System

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SPECIFICATION

1. Title of the Invention

Mobile-Object Communication System

2. Scope of Patent Claims

(1) A mobile-object communication system characterized as follows: in a mobile-object communication system composed of a zone-switching system consisting of a stationary terminal and a base station as well as a mobile object equipped with a GPS receiver and mobile-object communication equipment, the mobile object transmits its position, which is demodulated by the said GPS receiver, from the said mobile-object communication equipment; the said stationary terminal and base station receive the said mobile object's physical (geographical) position; after the mobile object's physical position is determined, it is used to switch the physically determined in-range zone for the mobile object.

3. Detailed Description of the Invention

(a) Field of Industrial Utilization

This invention concerns a GPS system to be implemented globally as well as a mobile-object communication system that controls zones using a zone switching system for car telephones, teleterminals, etc.

(b) Prior Art

For communica...n with such mobile objects as car telephones, portable telephones, and teleterminals, a zone switching-based mobile-object communication system is used to allocate many subscriber lines and use frequencies efficiently.

In this zone switching method, the service area is divided into many areas called zones, and a terminal station is provided for each divided zone. Here, frequencies can be reused because zones are separated far enough to prevent interference at a given frequency. As a result, frequencies can be used efficiently, and the number of allocated circuits can be increased.

An example of this zone method is shown in Figure 3.

In Figure 3, (a), (b) and (c) are models of the one-service-area, one-zone method, the medium-zone method, and the small-zone method, respectively.

In the figure, circle 21 indicates the service area. The zones are hexagonal, for example. A, B, C, and D are the mobile-object communication frequencies used in the zone.

In Figure 3(a), the service area consists of only one zone, so frequencies A, B, C, and D are all used. In Figures 3(b) and 3(c), adjacent zones have different frequencies (A, B, C, D) to prevent interference.

The number of available circuits for each of the said methods is computed below.

Assuming a 10-channel circuit is allocated per frequency (A, B, C, D), the totals are as follows:

- One-service-area, one-zone method

  10 x 4 = 40 channels

- One-service-area, medium-zone method

  12 x 10 = 120 channels (including partially out of area)

- One-service-area, small-zone method

  20 x 10 = 200 channels (including partially out of area)

With smaller zones, the frequencies can be reused, thereby ensuring many circuits.

In a mobile-object communication system, therefore, it is desirable to reduce the zone area.

(c) **Problems That the Invention is Intended to Solve**

The following two systems are required to implement a mobile-object communication system that uses such a zone-switching method:

(1) System for detecting the position of a mobile object

(2) System for inter-zone control during mobile-object movement

These two systems are described below.

(1) System for detecting the position of a mobile object

Because the mobile object transmits and receives, it is necessary to determine its current in-range zone.

Below, this system will be explained for a car telephone.

During transmission from a mobile-object station, the radio wave is received by numerous surrounding terminal stations (7 stations, for example), and the station where the wave's electric intensity is highest is registered as the in-range station and is responsible for transmission and reception.

On the other hand, so that it can continuously receive during reception, the mobile-object station continuously monitors the terminal station's transmission signal. Similarly, its own in-range zone is determined using the field intensity. After the in-range zone changes, the zone shift signal is sent, notifying the base station of the zone shift. At the base station, this signal triggers the reregistration of the mobile station's position, allowing the mobile object to be called at any time.

In this manner, the base station can always detect the in-range zone of the mobile object when it transmits or receives. This system enables communication by allocating frequencies in a zone.

(2) System for zone* control during mobile-object movement

In the zone switching method, particularly in the small-zone method, it is possible that the mobile object will move during transmission or reception (during circuit communication) and cross into another zone. As a result, it is necessary to use a system that maintains an unbroken circuit, even after the zone changes. This system is called inter-zone control.

The in-range zone terminal station decides that a mobile object has arrived at a zone border when the intensity of the field received from the mobile object drops. Adjacent terminal stations detect the field intensity, and the station with the strongest field intensity is chosen as the next in-range zone. Then the channel is switched to maintain the circuit.

In this system, even while a mobile object moves across several zones, an unbroken circuit is maintained, thereby enabling communication.

In such a system that controls the in-range zone, the following problems occur:

(i) A directionless scalar value called field intensity is used when determining the mobile object's position and the in-range zone. As a result, without knowing the mobile object's definite position, it is necessary to receive at all terminal stations capable of reception. Then the in-range zone station is determined by measuring the field intensities and then comparing the results of these measurements.

Next, Figure 5 will be used to explain what happens when the reception field intensity drops while a mobile object moves. This figure is a model of field intensity distribution. As a general rule, the field intensity distribution is equal in concentric circles on the plane of a map (when the transceiver antenna is omnidirectional). So, the circles of zones (a) - (i) in the figure indicate the field intensity regions where transmission and reception are possible.

In zone (a), circle 22 is the region of strong field intensity, and the cross-hatched area 23 is the region of weak field intensity.

When the mobile object crosses into another zone while moving, the field intensity drops and the system switches to the next in-range zone station, thereby maintaining the circuit. When the field intensity is measured using a ground-based antenna, however, the field intensity drops due to the presence of a screen, a propagation path problem, multiple paths, fading, etc. This region (i.e., the weak field intensity region) is the indeterminately wide region 23 in the figure.

As a result, when the field intensity drops at a terminal station and control is switched to the terminal station for the next in-range zone, the mobile object is at some unknown position within the shaded area of the weak field intensity region 23. So, the field intensity is measured at all adjacent zone terminal stations (in this example, the eight zones (b) - (i)), and the results of these measurements are compared. The determination of the new in-range zone imposes major

* Translator's note: This is "inter-zone" in previous text.

burdens on all adjacent zone stations, such as the allocation of channels for the new in-range zone. These burdens result because it is unclear which adjacent zone station the mobile object is currently near and whether or not the mobile object is moving.

(ii) As mentioned in problem (i), the field intensity varies due to screens, propagation path problems, fading, multiple paths, etc. As an example, the fading data for a car telephone are shown in Figure 4. These data are for an automobile's travel through about 10 m of an urban area. The received field intensity is expressed in decibels.

Because this always produces large variations in field intensity, there is a risk of selecting the wrong zone, for the following reason. In weak field intensity regions (particularly at zone boundaries), even if the mobile object is in in-range zone (a), an adjacent zone station may decide that the field intensity is weak.

During inter-zone control, however, while a mobile object moves between zones in the sequence (a) → (b) → (a) → (b) (for example, at zone boundaries), the station with the maximum reception field intensity also changes in the sequence (a) → (b) → (a) → (b), and the in-range zone also changes in the sequence (a) → (b) → (a) → (b). This is generally called the fluttering phenomenon.

However, as in the previous example, when the mobile object moves at the periphery of a zone where the field intensity is comparatively weak, the field intensity fluctuates due to fading, screening, etc., even though the mobile object remains in the same zone, so there is a risk of this being regarded as the fluttering phenomenon. As a result, because the mobile object is in the same zone, it is necessary to set up and control a circuit channel in both zones, even though the circuit channel should be handled only by station (a). This results in such problems as a drop in radio wave utilization efficiency and an increase in the control station load. This phenomenon may be exacerbated if either the zone size or the transceiver power is reduced.

Considering these problems, this invention aims at providing a mobile-object communication system with in-range control that is more accurate, provides simpler control, and improves radio wave utilization efficiency. To this end, the in-range zone is determined and the direction of motion is obtained by providing directly the mobile object's physical position (latitude and longitude), without using field intensity values, which lack direction and measurement stability, when the mobile object's position and in-range zone are being determined.

(d) Means of Solving the Problems

This invention has the following structure. In a mobile-object communication system based on zone switching, the mobile object demodulates using a GPS receiver, and the obtained position information is transmitted to a stationary terminal and base station. The position of the mobile object is determined from this physical information, and the in-range zone is determined.

(e) Function of the Invention

In this invention, the in-range zone is determined by allocating terminal station zones, which are predetermined physically (geographically), based on the mobile object's physical (geographical) position information, taking into consideration radio wave propagation, etc.

Because this invention eliminates uncertainty regarding the current position—the cause of conventional problems—and enables the precise determination of the direction of motion and the transition zone, inter-zone control is simplified and radio waves are utilized effectively.

Because a mobile object's position can be confirmed continuously and with high precision, the system can also be used to control the motion of individual mobile objects.

(f) Examples

An example of this invention is shown in Figure 1.

In the figure, 1 is the mobile-object communication equipment, 2 is terminal station (a), 3 is terminal station (b), and 4 is the controller for the mobile-object communication system.

13 and 14 are wires connecting the controller 4 with terminal stations (a) and (b) (2 and 3), respectively. These wires carry terminal-station control signals.

The structure of the communication equipment will be explained next. The mobile-object communication equipment 1 consists of the GPS receiver 5 and its antenna 7 as well as the mobile-object communication transceiver 6 and its antenna 8. Terminal stations (a) and (b) (2 and 3, respectively) consist of transceivers and terminal controllers 10 and 12, respectively, as well as antennas 9 and 11, respectively.

In the figure, the radio wave 15 is the wave (frequency) with the frequency used for communication with the mobile object.

Using this example, the operation of the mobile-object communication system will be explained below.

First, the mobile-object communication equipment 1 determines its physical position (latitude, longitude) using the GPS receiver 5.

The structure of the GPS receiver 5 is as follows.

At present, a mobile object's position is determined using a global positioning system (GPS) that uses artificial satellites that transmit microwaves. This system allows one to determine his or her position with high precision, anywhere on earth.

Furthermore, the mobile object contains a GPS receiver that receives and demodulates the signal from the artificial satellite (GPS satellite). The latitude, longitude, and altitude of the GPS receiver are determined geometrically with high precision.

In the GPS, GPS satellites are launched so that at least four are always visible from the ground. On the other hand, mobile objects on the ground are equipped with GPS receivers that receive radio waves from the satellites. The GPS receiver determines the position of each satellite by solving Kepler's equations using the satellite orbital data contained in the (approximately 1-2 GHz) signals received at the GPS receiver from the satellites. Next, the distance from each satellite to the mobile object is determined using the propagation time of the radio waves sent from the satellites. The mobile object's position is computed by solving simultaneous equations using this data. (See the December 1984 issue of *Electronics*, published by Ohm-Sha.)

The position data obtained using the said GPS receiver 5 is transmitted as the current position of the mobile object, via the mobile-object communication equipment 1 to the terminal station (a) 2. Either the mobile-object communication system controller 4 or the terminal controller 10 in the terminal station (a) 2 confirms that the mobile object's in-range zone is that of terminal station (a) 2, based on the terminal station's zone information, which is predetermined physically (geographically) using radio wave transmissions, and based on the physical (geographical) position of the mobile-object communication equipment. The confirmation is registered, and the terminal station (a) 2 takes over transmission and reception.

If the in-range zone becomes terminal station (b) 3 while the signal is received by terminal station (a) 2, the in-range zone is confirmed to be terminal station (b) 3, and terminal station (b) 3 takes over reception. Figure 6 is a flow chart showing an example of such connection control.

In the flow chart, the left side shows the mobile-object communication equipment and the right side shows the base control station's operation process.

The GPS receiver 5 built into the mobile-object communication equipment 1 continuously performs GPS reception (24), computes the mobile object's position data (25), and supplies the position data to the mobile-object communication transceiver 6.

When the mobile-object communication transceiver 6 is turned on, it receives the terminal station code for the in-range zone's control channel (26). If it differs, the transceiver sends and (28) and receives (29) its own ID code and position signal, according to the communication procedure. At the controller 4 side, the controlling terminal station is determined (31) (32) using its physical position information. In this manner, the controlling terminal station is determined continually based on the physical position, and the code for this terminal equipment is registered in the mobile-object communication equipment 1 (27) (28) (29) (30).

During reception and transmission (33), a connection is established (34) (38) according to the ground-station connection procedure. At the mobile-object communication equipment 1, the communication contents, including the position information, are exchanged (36) (39) until the switch command arrives. At the controller 4, the in-range zone is determined (40) based on the position information. When switching zones, the next zone is determined (41), the channel is determined (42), and the switch command, etc., (43) are issued. In this manner, the system controls zone switching, based on the physical position. After the switch command is issued, the mobile-object communication equipment and the ground station are connected to a new terminal station, according to the connection procedure (37) (34) (38).

During this operation, the following are verified, thereby solving conventional problems:

- mobile-object position detection and in-range zone determination during motion ①
- incorrect in-range zone determination ②

① In this invention, in order for the terminal station (a) 2 to determine the physical location of the mobile-object communication equipment 1, it is not necessary to use a complex position-detection process in which all surrounding stations receive and compare all field intensity levels.

4. Brief Explanation of the Drawings

Figure 1 is a configuration diagram for an example of the mobile-object communication system of this invention. Figure 2 is a configuration diagram of a concrete example of the mobile object. Figure 3 is a diagram of a model of the zone-type mobile-object communication system. Figure 4 is a waveform diagram of reception level variation at short intervals in an urban area. Figure 5 is a diagram illustrating zonal electric intensity distribution. Figure 6 is a flow chart for connection control in the mobile-object communication system.

The drawings consist of the following components:

1 Mobile-object communication equipment

2 Terminal station (a)

3 Terminal station (b)

4 Controller for mobile-object communication system

5 GPS receiver   6 Mobile-object communication transceiver

7 GPS antenna   8 Mobile-object communication antenna

9 Terminal-station (a) antenna

10 Terminal-station (a) transceiver and terminal controller

11 Terminal-station (b) antenna

12 Terminal-station (b) transceiver and terminal controller

13 Wire-based transmission path (a)

14 Wire-based transmission path (b)

15 Radio wave   16 Automobile

17 GPS antenna   18 Navigation system

19 Mobile-object communication equipment

20 Mobile-object communication equipment antenna

21 Service area   22 Strong electric field region

23 Weak electric field region

Agent: Atsushi Sugiyama, Patent Attorney

The direction of motion (i.e., the new in-range zone terminal station that takes charge next) can be confirmed definitely during motion, thereby eliminating the process of measuring and comparing the field intensity levels in all adjacent zones and requiring channel preparation only for the new in-range zone's expected terminal station. Because information processing also reveals when the mobile object will arrive in a new zone, it is possible to perform finer multichannel access, thereby increasing the access efficiency.

② The GPS receiver determines the physical location with an error of several tens of meters, thereby completely eliminating the mistaken switching to another zone, even at a zone's boundary or periphery. When small zones are used, the boundary region increases, so more mobile objects actually come and go between zones. However, depending on the database of the objects' speed and direction of motion, the signal processing software may allow overlap between zones, so it is also possible to use an efficient access method that forbids channel switching, etc.

In this mobile-object communication equipment 1, the GPS receiver 5 and mobile-object communication transceiver 6 are shown as integrated, but they may be separated, and the GPS receiver 5 may have separate operation and display functionality. Position information may be transmitted either continuously or intermittently, as appropriate for the system.

The second example is shown in Figure 2.

Here, the mobile-object communication equipment 19 is configured differently. Of the mobile-object communication system, only the mobile-object communication equipment is displayed.

In this example, 16 is the automobile; 17 is the GPS antenna; 18 is the navigation system, including GPS receiver; 19 is the mobile-object communication equipment; and 20 is the antenna for communication equipment 19.

Although the basic operation of this example is identical to that of the first example, the automobile's navigation system 19, which is equipped with a map display, etc., is also used for zone control (switching) in the mobile-object communication system. Because this navigation system 18 contains a GPS receiver, latitude and longitude can be determined. By transmitting this data to the mobile-object communication equipment 19, it is possible to form simple mobile-object communication equipment 19.

(g) Effects of the Invention

In the zone switching-based mobile-object communication system of this invention, the mobile object's zone is controlled at physical (geographical) position where the GPS receiver is used.

As a result, the mobile object's position is known unambiguously, so it is possible to improve access efficiency by precisely determining the terminal station and switching terminal stations during inter-zone motion. It is also possible to eliminate the burden on other terminal stations. Also, incorrect zone operation is eliminated, and it is possible to deal effectively with fluttering.

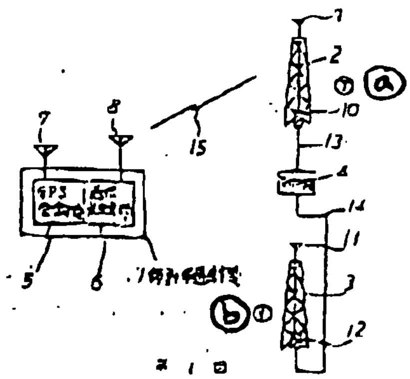

Figure 1

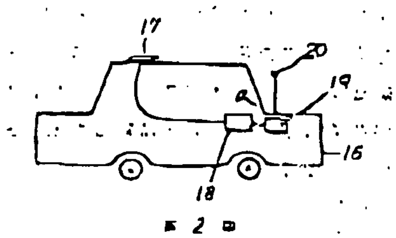

Figure 2

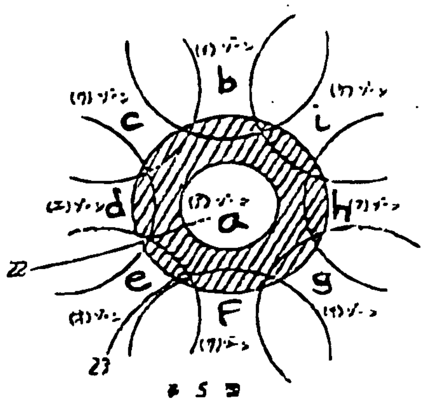

Figure 5

Key to Fig. 5

a	Zone A	b	Zone B
c	Zone C	d	Zone D
e	Zone E	f	Zone F
g	Zone G	h	Zone H
i	Zone I		

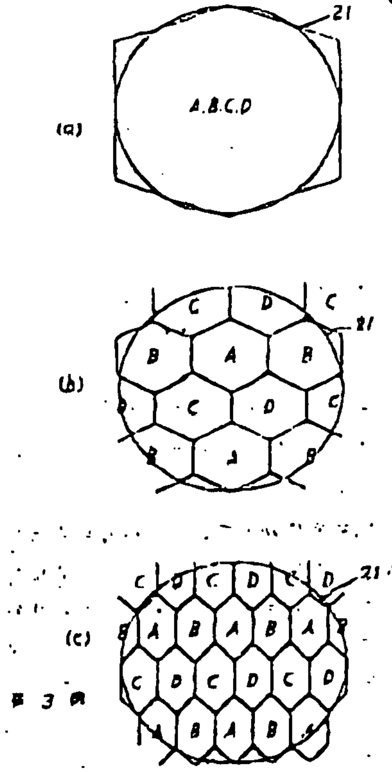

Figure 3

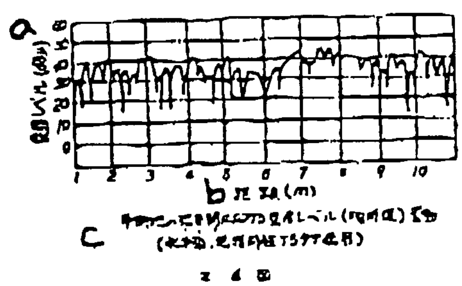

Figure 4

Key to Fig. 4

a Reception Level (dBμ)

b Distance (m)

c Reception Level Variation (Instantaneous Value) at Short Intervals in an Urban Area (Using a Level Surface and an Omnidirectional Antenna)

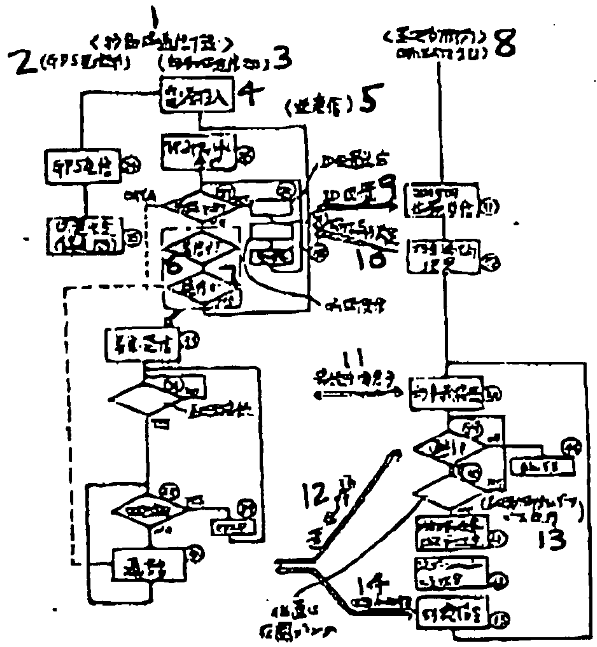

Figure 6

Key to Fig. 6

1 Mobile-object communication equipment

2 GPS receiver

3 Mobile-object transmitter

4 Power on

5 Transmission and reception

6 Receive?

7 Send?

8 Ground control station (including terminal station)

9 ID position

10 Terminal-station decision

11 Connection-procedure signal

12 Communication position

13 (using ground control station's database)

14 Switching-procedure signal

24 GPS reception

25 Position determination (latitude and longitude)

26 Control-channel reception

27 Registration necessary?

28 ID position transmission

29 Terminal-station reception

30 Registration

31 Physical-position reception

32 In-charge terminal-station determination

33 Reception and transmission

34 Ground-station connection

35 Switch and connect

36 Call

37 Switch

38 Mobile-station connection

39 Connected

40 Position in in-range zone?

41 Determination of next zone using mobile-object's position

42 Determination of next zone channel

43 Switch command

44 End